

Available online at www.sciencedirect.com

SCIENCE @ DIRECT®

Agriculture, Ecosystems and Environment 109 (2005) 87–96

**Agriculture
Ecosystems &
Environment**www.elsevier.com/locate/agee

Evolution of the vegetation of mown field margins over their first 3 years

Benny De Cauwer^a, Dirk Reheul^{a,*}, Katrien D'hooghe^a,
Ivan Nijs^b, Ann Milbau^b

^a *Department of Plant Production, Faculty of Agricultural and Applied Biological Sciences, Ghent University, Coupure Links 653, B-9000 Ghent, Belgium*

^b *Research Group of Plant and Vegetation Ecology, Department of Biology, University of Antwerp, Universiteitsplein 1, B-2610 Wilrijk, Belgium*

Received 29 April 2004; received in revised form 14 January 2005; accepted 15 February 2005

Abstract

Early succession of newly created sown/unsown margin strips on ex-arable land, managed by two cuttings per year with/without removal of cuttings, was characterised by the replacement of annuals in favour of perennials, a steady increase in the importance of monocotyledons and a decrease in non-nitrogen-fixing dicotyledons. Mowing with removal of cuttings delayed this succession pattern.

Sorenson's qualitative similarity index revealed that species composition of the sown communities in terms of species occurrence became increasingly similar to the unsown plots. Furthermore, convergence in vegetation composition between sown and unsown plots occurred also in terms of species importance as assessed by Sorenson's quantitative index. Similarity, in species, importance was significantly enhanced by cutting with removal of cuttings.

During the first three successional years, species diversity of sown and unsown communities converged in time, irrespective of mowing regime or location. The decrease in species diversity, number and density of sown wildflowers was more pronounced under a mowing regime without removal of cuttings. The annual addition of mown roadside herbage significantly enhanced species-richness, but not the importance of dicotyledons.

© 2005 Elsevier B.V. All rights reserved.

Keywords: Species-richness; Mowing regime; Succession; Similarity; Roadside herbage; Native wildflowers

1. Introduction

Despite an ongoing reduction in field boundary habitats (Chapman and Sheail, 1994), a range of public initiatives has resulted in the creation of new field margin features on ex-arable land in Northern and

* Corresponding author. Tel.: +32 9 264 60 96;
fax: +32 9 264 62 24.

E-mail address: Dirk.Reheul@Ugent.be (D. Reheul).

Western Europe, notably conservation headlands and margin strips. Support mechanisms exist to encourage farmers to create new habitats, to restore old ones or expand existing boundaries by means of margin strips, to restore the landscape connectivity, to care for small landscape elements. Expanding existing field boundaries is generally done by taking the outer metres of an arable field out of production and allowing it to regenerate naturally or sowing it to grass or a grass/forbs mixture, usually under a mowing regime (e.g. Dunkley and Boatman, 1994; Hart et al., 1994; Marshall and Nowakowski, 1992; Smith and MacDonald, 1989).

To evaluate the long-term success of sown and unsown margin strips, it is essential to record vegetation succession, species composition and richness over time. According to Hodgson (1989), the succession of naturally revegetated strips is characterised by an initial dominance of annuals and short-lived species, which are with time, typically replaced by perennial non-woody species, and secondly, if no mowing regime is applied by shrubs and trees. After 3 years, species-richness, biomass production and monocotyledon/dicotyledon ratio in grass, grass/wildflower strips and natural regeneration strips, mown once a year, converged to the level of the pre-existing boundary, and this in three countries; UK, France and The Netherlands (Kleijn et al., 1998; Marshall et al., 1994). Kleijn et al. (1997) found within 3-year-old strips mown once a year, that strips sown with a rich grass/wildflower mixture had higher species-richness than strips sown to perennial ryegrass or strips left to revegetate spontaneously because of limited colonisation by species from the pre-existing boundary. West and Marshall (1996) also found that mown naturally regenerated plots had lower vegetation cover and lower species diversity than mown sown plots, but species numbers remained stable in the second year, whereas they decreased in the sown plots.

Unfortunately many succession studies concerning margin strips do not contain unsown plots. It is therefore impossible to know how effective the addition of seed mixtures has been in accelerating or diverting succession or species composition. Furthermore, information is lacking concerning vegetation succession and botanical composition of sown and unsown strips under different cutting regimes during the first successional years.

According to Marshall (1998), seed mixtures with fine grasses and wildflowers are most successful on infertile soils with regular mowing. Cutting yearly in spring and late summer, with removal of cuttings, reduced the rate of species loss in a sown grass/wildflower field margin strip over a 5-year period and was recommended for maintaining plant species diversity (Marshall and Nowakowski, 1995).

This study examines the effects of sown and unsown margin strips on early vegetation succession, species-richness and composition of ex-arable land under different cutting regimes. In particular, the following questions are addressed: (1) is there any potential for naturally regenerated strips to develop into floristic diverse plant communities or are they depauperated of species? (2) Which mowing regime of the newly created communities maximizes species-richness and how does the cutting regime direct biodiversity and vegetation succession? (3) What is the success of introducing seed mixtures differing in seed provenance to recreate a diverse semi-natural community? (4) Is the application of species-rich roadside herbage useful to enhance botanical diversity? (5) And finally, is there any similarity in the vegetation between unsown and sown communities?

2. Material and methods

In June 2001, a field margin experiment was established on nutrient-rich arable land in a split plot design with four plant communities, three cutting treatments and three blocks. The plant communities were randomized within three blocks and the three cutting treatments were randomized within the plant communities. The split plot design was installed on two contrasting soil types in Belgium, province of West Flanders namely at Poperinge (SITE1: 50°52'N, 2°45'E, drained sandy loam, pH 6.8 (KCl), 1.5% C) and at Beernem (SITE2: 51°09'N, 3°20'E, sandy, pH 5.7 (KCl), 3.3% C). Analysis of top soil (0–30 cm) of SITE1 showed that extractable P and K were 27 and 31 mg/100 g soil, respectively, and total mineral N was 43 kg ha⁻¹. Analysis of top soil (0–30 cm) of SITE2 showed that extractable P and K were 75 and 31 mg/100 g soil, respectively, and total mineral N was 113 kg ha⁻¹. The experimental sites (360 m × 10 m each) were ploughed from Italian ryegrass in

May 2001 and divided in 36 plots (10 m × 10 m each) arranged along a watercourse at SITE1 or an east–west oriented tree row at SITE2.

Apart from an unsown spontaneously evolving plant community (CONTR.), three different sown communities were studied (MIXT1, MIXT2, MIXT3). MIXT1 was established with a seed mixture of 63 species comprising native seeds of local provenance, for MIXT2 a commercially available seed mixture of 77 species comprising species completely unrelated to the sowing region was used. The initial composition of MIXT3 was identical to that of MIXT2, but once a year, seed-rich herbage originating from neighbouring roadsides was added. Roadsides were cut around the end of September. The fresh unchopped herbage was immediately transported and spread uniformly over the plots a ratio of approximately 5000 kg fresh herbage per hectare. Principal seed bearing species were *Daucus carota* L., *Centaurea jacea* L., *Tanacetum vulgare* L., *Plantago lanceolata* L., *Torilis japonica* DC, *Pulicaria dysenterica* Bernh. Plant species in MIXT1 and MIXT2 were selected from a

wide range of vegetation types: annual and perennial forbs from dry to moist grassland and perennial forbs thriving in nutrient-rich soils. Nitrogen-fixing dicotyledons were incorporated to improve the nutritional value of the biomass.

In the installation year 2001, the field margin plots were cut once on 15 September with removal of the cuttings. During the subsequent years 2002 and 2003, the experimental plots were cut twice per year with cuttings either left or removed resulting in three different cutting treatments: REMOV0, no removal of cuttings; REMOV1, removal of first cutting; REMOV2, removal of both cuttings. The cutting height was 5 cm. To allow the seed set of a major part of the species and to allow the establishment of young seedlings, the first mowing date was postponed till 15 June. The vegetation was cut a second time around 15 September. Care was taken to reduce seed dispersal due to removal of the cuttings.

Vegetation succession in the field margin occurred under zero fertilisation and no herbicide and pesticide

Table 1

Crops adjacent to the field margins (period 2001–2003): crop rotation, fertilizer and herbicide application

	Year		
	2001	2002	2003
SITE1			
Crop	Sugar beet	Winter wheat	Silage maize
Fertilizers	122 N	220 N	180 N
	35 P	30 P	35 P
	280 K	80 K	65 K
Herbicides ^a	1 × Pyramin (3 L ha ⁻¹)	1 × IP flo (3 L ha ⁻¹)	1 × Aspect (2 L ha ⁻¹)
	4 × Betanal progress (1.0, 1.0, 1.2, 1.5 L ha ⁻¹)	1 × Hussar (0.2 L ha ⁻¹)	1 × Mikado (1 L ha ⁻¹)
	3 × Goltix (0.50, 0.25, 0.75 kg ha ⁻¹)		
	2 × Safari (30, 30 g ha ⁻¹)		
	1 × Fervinal (1.25 L ha ⁻¹)		
SITE2			
Crop	Potato	Leek	Carrot
Fertilizer	222 N	160 N	0 N
	60 P	25 P	0 P
	100 K	225 K	150 K
Herbicide	— ^b	— ^b	— ^b

For abbreviations, see Section 2.

^a Pyramin (520 g L⁻¹ chloridazon); Betanal progress (62 g L⁻¹ fenmedifam + 128 g L⁻¹ ethofumesaat + 16 g L⁻¹ desmedifam); Goltix (700 g L⁻¹ metamitron); Safari (50% triflusaluron-methyl); Fervinal (120 g L⁻¹ sethoxydim); IP flo (500 g L⁻¹ isoproturon); Hussar (5% iodosulfuron + 15% mefenpyr-diethyl); Aspect (250 g L⁻¹ atrazin + 250 g L⁻¹ flufenacet); Mikado (300 g L⁻¹ sulcotrione).

^b No use of herbicides, organic farming.

use. Adjacent crops and their fertilizer and herbicide inputs are shown in Table 1.

The botanical composition of the vegetation was recorded twice per year on 15 July and 15 October, 30 days after every mowing date. Species occurrence was recorded within the central 4 m × 4 m area of each 10 m × 10 m plot. Species importance was derived from presence in 16-randomly placed quadrats (13 cm × 13 cm) within the central 4 m × 4 m area of each plot according to the combined frequency–rank method of De Vries and de Boer (1959). Species presence was expressed in terms of importance (%) based on the ranking of biomass contributed by the various plant species within each quadrat. The percentage of importance (I%) was calculated as follows: within each quadrat ranks were assigned according to the estimated biomass of each species: rank 1, for the species with the highest contributing in total biomass; rank 2 for the second highest contribution, etc. Then, for each species, the sum, I_{tot} was made of the number of times, ranks 1–3 was assigned in all quadrats multiplied by a factor 3, 2, and 1, respectively. The I% of an individual species was then calculated as I_{tot} of that species divided by the sum of I_{tot} of all occurring species. The original method was modified for use in species-rich grassland containing many dicotyledons: size of quadrats was increased relative to the original 10 cm × 10 cm in order to allow each occurring species, also broad-leaved dicotyledons, to be recorded with an equal probability.

The botanical composition in terms of importance of functional groups was recorded in time by calculating the percentile contribution, often functional groups to the total importance (=100%). Species were classified into the following functional groups: annual and perennial legumes, annual and perennial sown or spontaneous non-fixing dicotyledons, annual and perennial sown or spontaneous monocotyledons. The I% of a functional group was calculated by adding the I% of all contributing species of that group.

Both the total number of species (species diversity) and the number of sown wildflower species (spp./16 m²) were determined by recording the presence or absence of each individual species within the central 4 m × 4 m area. Similarity of vegetation development between sown and unsown plant communities within cutting treatments was compared using both Sorenson's qualitative measure, C_s and Sorenson's quanti-

tative measure, C_N (Magurran, 1988). Index C_s was solely based on species occurrence, whereas index C_N incorporated both species occurrence and species importance. In this paper, C_s was calculated within each block as $2j/(a+b)$, where j is the number of species common to both communities A and B and a and b are the number of species of communities A and B, respectively. C_N was calculated within each block as $\sum 2N_j/(N_a + N_b)$, where N_a and N_b was the total importance of the communities A ($N_a = 100$) and B ($N_b = 100$), respectively, and N_j was the lower of the two percentages of importance for common species of both communities.

To determine the pattern of succession in time, regression analysis was used (SPSS10.0 for Windows). Furthermore, S-plus 2000 for Windows was used to carry out the statistical computations for a split plot design.

3. Results

After 3 years of succession total species diversity was significantly altered by the plant community ($p = 0.03$) and the cutting treatment ($p = 0.001$), but not by the location. However, a significant interaction between location and plant community occurred ($p = 0.03$). At SITE1, CONTR. (16.1 spp.) was species-richer than MIXT2 (14.9 spp.) and MIXT1 (14.3 spp.) (LSD = 1.9 spp.). At SITE2, the highest species-richness was observed in MIXT1 (18.7 spp.) followed by CONTR. (18.2 spp.) and MIXT2 (12.8 spp.) (LSD = 1.9 spp.). The addition of roadside herbage significantly increased species-richness with approximately 2 spp./16 m² on both locations (SITE2: MIXT3, 14.6 spp. versus MIXT2, 12.8 spp.; SITE1: MIXT3, 16.8 spp. versus MIXT2, 14.9 spp.).

The species-richness was significantly higher for REMOV2 (17.2 spp.) than for REMOV0 (14.4 spp.) (LSD = 0.7 spp.). REMOV1 responded intermediary with 15.8 spp.

During the first three successional years, species diversity of sown communities decreased in time under REMOV0 (Table 2). Species diversity of MIXT2 decreased between 2001 and 2003 irrespective of mowing regime or location with significant slopes of regression equations at SITE2 ($0.04 > p > 0.001$) and non-significant slopes at SITE1. Similarly, species

Table 2

Species diversity (spp./16 m²) during succession (2001–2003) and slopes of linear regression of species diversity over time for four sown/unsown plant communities under cutting with or without removal of all cuttings

Location	Cutting treatment	Plant community	Before mowing (September 2001)	After mowing ^a					Slopes ^b
				M1 (October 2001)	M2 (July 2002)	M3 (October 2002)	M4 (July 2003)	M5 (October 2003)	
SITE1	REMOV0	CONTR.	34.3	8.3	24.7	21.0	17.0	16.3	−0.82
		MIXT1	33.7	17.3	15.7	17.7	15.3	14.0	−3.99
		MIXT2	49.7	18.0	15.7	14.3	17.0	12.7	−4.55
		MIXT3	48.7	16.7	19.0	16.3	23.3	17.7	4.73
	REMOV2	CONTR.	34.3	10.0	24.7	26.7	16.0	16.0	−1.18
		MIXT1	33.7	18.0	18.7	19.7	18.0	15.0	−3.30
		MIXT2	49.7	19.0	17.7	18.3	15.7	15.0	−5.57
		MIXT3	48.7	19.0	27.3	15.7	21.3	18.3	−1.79
SITE2	REMOV0	CONTR.	13.7	14.0	19.3	18.0	15.7	16.0	0.65
		MIXT1	33.0	21.3	20.7	17.3	18.7	15.3	−6.92*
		MIXT2	42.0	25.3	14.0	11.7	12.0	11.3	−17.00***
		MIXT3	42.0	23.0	19.3	12.3	18.3	12.0	−11.30*
	REMOV2	CONTR.	13.7	10.3	17.0	20.7	15.3	19.0	8.18
		MIXT1	33.3	18.3	24.7	25.7	23.0	20.3	2.00
		MIXT2	42.0	24.3	22.7	17.3	17.0	14.7	−13.00*
		MIXT3	42.0	24.0	28.0	13.7	26.6	19.0	−3.36

For abbreviations, see Section 2.

^a M, number of subsequent cutting and associated monitoring date.

^b Slopes of regression of species diversity on time (October 2001–October 2003).

* $p < 0.05$.

*** $p < 0.001$.

diversity of MIXT1 decreased (not significant) at SITE1 irrespective of mowing regime. However, at SITE2 species, diversity of MIXT1 increased (not significant) under REMOV2, whilst it significantly ($p = 0.05$) decreased under REMOV0. Obviously, commercial species were less persistent than native species since all slopes were more negative for MIXT2 than for MIXT1. At SITE2, the decrease in species diversity of sown communities was hastened under REMOV0, since slopes were more negative under REMOV0 than under REMOV2.

Species diversity of CONTR. slightly decreased at SITE1, but increased at SITE2 irrespective of mowing regime (Table 2). As for the sown communities, the increase in species diversity of CONTR. at SITE2 was lower for REMOV0 than REMOV2. Since initially species diversity was significantly higher for the sown communities and since the unsown community revealed a higher increase (SITE2) or lower decrease (SITE1) in species diversity, species diversity of sown and unsown communities converged during the first three successional years, irrespective of mowing regime or location.

The annual addition of roadside herbage after the September cutting caused an annual peak (15 July) in species-richness. However, the survival of introduced species by the addition of roadside herbage was unstable, which could explain the whimsical pattern (Table 2) of species-richness in time. Furthermore, all slopes of regression equations of MIXT3 were less negative than the corresponding equations of MIXT2. This means that the addition of roadside herbage delayed the loss of species.

3.1. Fate of sown wildflowers

Upon establishment, 72% of the sown wildflower species emerged in MIXT3 and MIXT2, and 42% in MIXT1 (Table 3). During the following years, the number of sown wildflowers decreased significantly, irrespective of plant community, mowing regime or location.

However, diversity of sown wildflower species (except for SITE1 and MIXT3 at SITE2) decreased at higher rate under REMOV0 since all slopes of regression equations were more negative under

Table 3

Number of surviving sown wildflower species (spp./16 m²) during succession (2001–2003) and slopes of linear regression of number of wildflower species over time for four sown plant communities under cutting with or without removal of all cuttings

Location	Plant community	Cutting treatment	Before mowing (September 2001)	After mowing ^a					Slopes ^b
				M1 (October 2001)	M2 (July 2002)	M3 (October 2002)	M4 (July 2003)	M5 (October 2003)	
SITE1	MIXT1	REMOV0	19.0	7.0	3.7	4.0	3.7	3.7	−3.94 [*]
		REMOV2	19.0	7.3	7.7	5.7	5.3	4.0	−4.92 ^{**}
	MIXT2	REMOV0	41.0	6.7	5.7	4.7	4.7	3.0	−4.31 ^{**}
		REMOV2	41.0	8.0	7.3	6.3	4.3	4.0	−5.94 [*]
	MIXT3	REMOV0	41.0	5.3	7.0	5.0	5.3	4.0	−1.87
		REMOV2	41.0	6.7	8.7	4.3	6.3	4.7	−2.65
SITE2	MIXT1	REMOV0	19.0	8.3	6.7	6.0	4.7	3.3	−6.46 ^{***}
		REMOV2	19.0	6.3	7.0	10.0	6.7	6.3	−0.41 ^{**}
	MIXT2	REMOV0	42.0	7.3	2.7	3.0	1.0	1.0	−8.24 ^{***}
		REMOV2	42.0	8.0	4.7	3.3	1.7	2.3	−8.07 ^{***}
	MIXT3	REMOV0	42.0	5.3	5.3	3.3	2.3	1.7	−5.38 [*]
		REMOV2	42.0	8.3	7.7	3.0	4.7	3.3	−6.51 [*]

For abbreviations, see Section 2.

^a M, number of subsequent cutting and associated monitoring date.

^b Slopes of regression of species diversity on time (October 2001–October 2003).

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$.

REMOV0 than under REMOV2, irrespective of plant community (Table 3).

In October 2003, the cutting treatment ($p = 0.005$) significantly determined the total number of surviving sown wildflower species. The highest number of sown wildflower species was recorded under REMOV2 (4.1 spp.), which significantly differed from REMOV1 (3.2 spp.) and REMOV0 (2.8 spp.) (LSD = 0.4 spp.).

3.2. Composition

During succession, the I% of perennials significantly increased at the expense of the I% of annuals, which significantly decreased irrespective of plant community, mowing regime or location. In the installation year, annuals showed a high I% and were even dominant in the unsown community. The decrease in I% of annuals occurred within all functional groups (monocotyledons, non-fixing dicotyledons and legumes). The increase in I% of perennials, on the other hand, was predominantly attributed to the increase of perennial monocotyledons and to a lesser extent to perennial non-fixing dicotyledons or legumes.

The significant decrease in I% of annuals and inversely the significant increase in perennials were

modified by mowing regime and plant community. The decrease (annuals) and increase (perennials) occurred at higher rate under REMOV0 (except for MIXT2 at SITE2) since slopes of linear regression equations were more negative and positive, respectively, for annuals and perennials. Similarly, in sown communities, the decrease of annuals and increase of perennials was hastened in the vegetation of MIXT2.

The I% of monocotyledons increased significantly in time, irrespective of mowing regime, plant community or location with highest rates within CONTR. and lowest in MIXT1. Furthermore, the I% of monocotyledons increased at higher rate under REMOV0 except for MIXT2 at SITE2. The increase in I% of monocotyledons was attributed to the increase in I% of perennial monocotyledons (both sown and unsown) since annual monocotyledons (sown and unsown) decreased in time.

Three years after installation, the actual I% of monocotyledons was significantly determined by location ($p = 0.04$), plant community ($p = 0.03$) and mowing regime ($p = 0.05$). SITE2 was more grassy than SITE1 (69.0% versus 59.4%) (LSD = 2.0%). The fraction of monocotyledons was lowest in MIXT1 (60.1%) followed by CONTR. (67.0%) and MIXT2

(69.7%) (LSD = 3.5%). The addition of roadside herbage provoked a less grassy vegetation (MIXT3, 60.0% versus MIXT2, 69.7%). Under REMOV0, communities were more grassy than under REMOV1 and REMOV2 (66.8% versus 63.9% versus 61.9%) (LSD = 2.5%).

The I% of both annual and perennial legumes significantly decreased over time in all sown communities. This decrease in I% in sown communities was more pronounced under REMOV0 than under REMOV2. At SITE2, the decrease of legumes was not affected by mowing regime since slopes of linear regression equations were similar for REMOV0 and REMOV2. In CONTR., the I% of legumes decreased at SITE2, but not at SITE1, where they significantly expanded at high rate, the significant expansion was hastened under REMOV2. Three years after installation the actual I% of legumes was significantly determined by location ($p = 0.02$), plant community ($p = 0.003$) and mowing regime ($p = 0.03$). The I% of legumes at SITE1 was two-fold of the I% at SITE2 (32.7% versus 15.4%) (LSD = 2.3%). MIXT1 had a higher fraction of legumes than MIXT2 (29.1% versus 22.3%) (LSD = 4.3%). CONTR. showed the lowest fraction of legumes (12.6%). The addition of roadside herbage increased significantly the I% of legumes (32.1% in MIXT3 versus 22.3% in MIXT2). The I% of legumes was significantly higher under REMOV2 (REMOV2, 26.2%; REMOV1, 24.7%; REMOV0, 21.2%; LSD = 1.8%). During succession, the I% of non-fixing dicotyledons significantly decreased at the benefit of the monocotyledons, which significantly increased in time, irrespective of mowing regime, location or plant community. The highest rate of change was found, similar as for the I% of monocotyledons, in CONTR. followed by MIXT2. At SITE2, the rate of decrease of non-fixing dicotyledons was higher under REMOV0 than under REMOV2 except for MIXT2. At SITE1, however, the rate of decrease was not affected by the mowing regime except for MIXT2, in which the decrease was faster under REMOV0. The I% of annual non-fixing dicotyledons significantly decreased in time, irrespective of plant community, mowing regime or location. In sown plots, the I% of perennial sown non-fixing dicotyledons significantly decreased in time, irrespective of mowing regime, location or plant community. At the contrary, the I% of perennial spontaneous non-

fixing dicotyledons increased slightly in time, except for MIXT2 at SITE1. In CONTR., the I% of perennial spontaneous non-fixing dicotyledons increased slightly at SITE2, but decreased significantly at SITE1. The I% of spontaneous non-fixing dicotyledons became inferior to the I% of spontaneous monocotyledons, irrespective of mowing regime, location or plant community, despite the initial higher I% of spontaneous non-fixing dicotyledons.

Three years after installation, the I% of non-fixing dicotyledons was significantly altered by location ($p = 0.04$) and plant community ($p < 0.001$), but not by the mowing regime. The I% of dicotyledons was twice as high at SITE2 than at SITE1 (15.6% versus 7.9%) (LSD = 1.6%). The highest fraction of dicotyledons was observed within CONTR. (20.4%) followed by the sown communities MIXT2 (10.8%) and MIXT1 (8.1%) (LSD = 2.5%).

3.3. Similarity of succession

In general, C_s significantly increased during the early succession period 2001–2003: all regression equations had a significant positive slope, with p -values between 0.05 and 0.0001 except for MIXT2 under REMOV2 (almost significant) (Table 4). This means that species composition of sown and unsown communities within mowing treatments became more similar in time. Furthermore at SITE2, but inversely at SITE1, slopes of all equations under REMOV2 were higher than under REMOV0, irrespective of plant community, indicating that similarity in species occurrence occurred at higher rate when cuttings were removed. At SITE2, slopes of equations were higher for MIXT3 with the addition of roadside herbage than for MIXT2, irrespective of mowing regime. A similar result was found under REMOV0 at SITE1.

C_N was determined by location. During succession, no significant change (except for MIXT2 under REMOV2) in C_N was observed at SITE2 with in general slightly negative slopes (except for the slightly positive slope of MIXT1 under REMOV0) and p -values between 0.971 and 0.240 (Table 4). At the contrary, C_N increased significantly between 2001 and 2003 at SITE1 with the slope of all linear equations being positive with p -values between 0.05 and 0.006. MIXT2 revealed higher rates of convergence than

Table 4

Slopes ($\times 10^{-4}$ per day) of regression equations of Sorenson's similarity measures between sown and unsown communities within cutting treatments, over time (period 2001–2003)

Comparison pair	C_N^a				C_s^b			
	SITE1		SITE2		SITE1		SITE2	
	REMOV0	REMOV2	REMOV0	REMOV2	REMOV0	REMOV2	REMOV0	REMOV2
MIXT1-CONTR.	2.572*	3.699**	0.044	−1.046	4.538**	3.454*	2.093*	2.193*
MIXT2-CONTR.	4.447*	5.573***	−0.526	−1.387*	3.806**	3.305**	1.826*	1.952
MIXT3-CONTR.	4.874**	4.563**	1.453	0.996	4.258***	2.848**	3.077*	4.209*

For abbreviations, see Section 2.

^a C_N , quantitative Sorenson's index.

^b C_s , qualitative Sorenson's index.

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$.

MIXT1 at SITE1. Similarly, rate of convergence was faster under REMOV2 than under REMOV0.

Three years after installation, C_N was significantly determined by the mowing regime ($p = 0.02$) and location ($p = 0.001$), but not by the plant community. C_N was significantly lower at SITE2 than at SITE1 (0.18 versus 0.39) (LSD = 0.04). C_N was significantly higher for REMOV2 (0.32) than for REMOV0 (0.23) (LSD = 0.03). At the end of 2003, C_N showed significant interaction between plant community and location ($p = 0.05$). At SITE2, C_N was not influenced by the plant community (MIXT2, 0.21; MIXT1, 0.21), whereas at SITE1, C_N was significantly higher for MIXT2 (0.45) than for MIXT1 (0.28) (LSD = 0.06).

4. Discussion

Species diversity of unsown and sown communities converged during the first three successional years after establishment on ex-arable land. So, species diversity on the long-term seemed unaffected by the type of plant community that was installed. Initially, species diversity was significantly increased by sowing species-rich mixtures. However, in the subsequent years, floristic diversity of sown communities decreased (commercial community) or remained stable (native community). Meanwhile, the unsown community became species-richer. This is in accordance with West and Marshall (1996), who found naturally regenerated plots to have lower species diversity than sown plots during the first year, but species numbers remained stable in unsown plots in the second year, whereas they decreased in the

sown plots. Also Marshall and Nowakowski (1995) found that over a 5-year period, species diversity of sown flower strips decreased in time on fertile soils. However, Kleijn et al. (1997) found that, after 3 years of succession, species numbers only reached considerable levels when species were sown, irrespective of any relationship between vegetation productivity and species-richness. The rates of successional changes in species diversity were significantly directed by the mowing regime and the plant community. The decrease in species diversity in sown communities was hastened under a mowing regime without the removal of cuttings and/or when the plant community was based on a commercial seed mixture of foreign provenance instead of a native seed mixture.

Three years after installation, species diversity was significantly higher under a mowing regime with complete removal of cuttings than under a regime with no or partial removal of the biomass. Indeed, the non-removed biomass hampered the growth in the aftermath and prevented the introgression of species. Also, Persson (1995) found that yearly mowing with removal of cuttings was necessary to keep high number of species in roadsides, especially the low-growing ones.

The annual addition of roadside herbage on margin strips offers opportunities to enhance species-richness. The annual addition of seed-rich roadside herbage significantly increased the floristic diversity with approximately 2 spp./16 m². The evolution of the species-richness in time was however irregular. A single addition of roadside herbage was not sufficient to increase species-richness in a sustainable way during the early successional stage. Many emerging species of

roadside provenance were subdued due to high vegetation productivity. The number of occurring sown wildflower species decreased in time in sown communities, irrespective of plant community, location or mowing regime. However, the decrease was hastened under a mowing regime without the removal of cuttings and/or when the plant community was based on a commercial seed mixture of foreign provenance instead of a native seed mixture.

Vegetation succession during the first three successional years caused drastic changes in the proportional importance of functional groups. Annuals, although initially highly present (even dominant in unsown plots), steadily decreased in importance, whilst perennials steadily increased in importance. These changes occurred at higher rate when cuttings were not removed and/or in vegetations based on commercial seed mixtures. Convergence in species occurrence between pairs of sown and unsown communities within mowing treatments was observed irrespective of sown communities or location. This is not in accordance with Warren et al. (2002) who found, over a 6-year period, that the cut and/or grazed vegetation in sown and non-sown plots, installed on ex-arable land, converged in terms of abundance of species rather than in the number of species they contained. After three successional years, similarity of species occurrence was no longer significantly determined by the type of plant community or mowing regime. However, dissimilar with species occurrence, convergence in species importance between pairs of sown and unsown communities within mowing treatments only occurred at SITE1 whilst a slight divergence was observed at SITE2.

This research revealed that the development of species-rich field margin strips was not strongly affected by the installed type of margin strip since species diversity converged in time, whether strips were sown or not. Convergence between unsown and sown margin strips occurred also in terms of species composition: unsown and sown strips became similar in time. Mowing without removal of cuttings significantly reduced species-richness, yielded more grassy margin strips and retarded similarity in species composition between sown and unsown margin strips.

As farmers are afraid of the development of weedy annual and rhizomatous species, they prefer a sown to a spontaneously emerging vegetation (Van der Meulen

et al., 1996). A cutting management fits into their perception of ‘clean’ fields. Hence, the promotion of field margins might be more successful, if farmers are advised to use a seed mixture upon installation of the margin, and if they are advised to cut the margin twice a year. Furthermore, a cutting management of productive vegetation with removal of the cuttings will accelerate mineral depletion of the soil, promoting the development of botanically diverse vegetation.

Acknowledgement

This research was supported by the Federal Office for Scientific, Technical and Cultural Affairs (Prime Minister’s Office, Brussels, Belgium) under the program Global Change, Ecosystems and Biodiversity.

References

- Chapman, J., Sheail, J., 1994. Field margins—an historical perspective. In: Boatman, N. (Ed.), *Field Margins: Integrating Agriculture and Conservation*. BCPC Monograph 58, The British Crop Protection Council, Farnham, Surrey, UK, pp. 3–12.
- De Vries, D.M., de Boer, T.A., 1959. Methods used in botanical grassland research in the Netherlands and their application. *Herbage Abstr.* 29 (1), 1–7.
- Dunkley, F.A., Boatman, N.D., 1994. Preliminary findings from a study of sown and unsown management options for the restoration of perennial hedge-bottom vegetation. In: Boatman, N. (Ed.), *Field Margins: Integrating Agriculture and Conservation*. BCPC Monograph 58, The British Crop Protection Council, Farnham, Surrey, UK, pp. 329–334.
- Hart, B.J., Manley, W.J., Limb, Davies, W.P., 1994. Habitat creation in large fields for natural pest regulation. In: Boatman, N., (Ed.), *Field Margins: Integrating Agriculture and Conservation*. BCPC Monograph 58, The British Crop Protection Council, Farnham, Surrey, UK, pp. 319–322.
- Hodgson, J.G., 1989. Selecting and managing plant materials used in habitat construction. In: Buckley, G.P. (Ed.), *Biological Habitat Reconstruction*. Belhaven Press, London, UK, pp. 45–67.
- Kleijn, D., Joenje, W., Kropff, M.J., 1997. Patterns in species composition of arable field boundary vegetation. *Acta Botanica Neerlandica* 46, 175–192.
- Kleijn, D., Joenje, W., Le Coeur, D., Marshall, E.J.P., 1998. Similarities in vegetation development of newly established herbaceous strips along contrasted European field boundaries. *Agri. Ecosyst. Environ.* 68, 13–26.
- Magurran, A.E., 1988. *Ecological Diversity and its Measurement*. Cambridge University Press, Cambridge, p. 179.
- Marshall, E.J.P., 1998. Guidelines for the Siting, Establishment and Management of Arable Field Margins, Beetle Banks, Cereal

- Conservation Headlands and Wildlife Seed Mixtures. Issue No. 2, IACR-Long Ashton Research Station, University of Bristol, p. 98.
- Marshall, E.J.P., Nowakowski, M., 1992. Herbicide and cutting treatments for establishment and management of diverse field margin strips. *Aspects Appl. Biol.* 29, 425–430.
- Marshall, E.J.P., Nowakowski, M., 1995. Successional Changes in Flora of a Sown Field Margin Strip Managed by Cutting and Herbicide Application. Brighton Crop Protection Conference—Weeds, The British Crop Protection Council, Farnham, Surrey, UK, pp. 973–978.
- Marshall, E.J.P., Thomas, C.F.G., Joenje, W., Kleijn, D., Burel, F., Le Coeur, D., 1994. Establishing vegetation strips in contrasted European farm situations. In: Boatman, N. (Ed.), *Field Margins: Integrating Agriculture and Conservation*. BCPC Monograph 58, The British Crop Protection Council, Farnham, Surrey, UK, pp. 335–340.
- Persson, T.S., 1995. Management of Roadside Verges: Vegetation Changes and Species Diversity. Ph.D. Thesis. Report 82. Department of Ecology and Environmental Research, Swedish University of Agricultural Sciences, Uppsala.
- Smith, H., MacDonald, D.W., 1989. Secondary succession on extended arable field margins: its manipulation for wildlife benefit and weed control. *Proceedings of the 1989 Brighton Crop Protection Conference—Weeds*, The British Crop Protection Council, Farnham, Surrey, UK, pp. 1063–1068.
- Van der Meulen, H.A.B., De Snoo, G.R., Wossink, G.A.A., 1996. Farmers' perception of unsprayed crop edges in the Netherlands. *J. Environ. Manag.* 47, 241–255.
- Warren, J.M., Christal, A., Wilson, F., 2002. Effects of sowing and management on vegetation succession during grassland habitat restoration. *Agri. Ecosyst. Environ.* 93, 393–402.
- West, T.M., Marshall, E.J.P., 1996. Managing sown field margin strips on contrasted soil types in three environmentally sensitive areas. *Aspects of Applied Biology*, vol. 44. Vegetation Management in Forestry, Amenity and Conservation Areas, pp. 269–276.